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(54) **Contact lens with continuously changing focal length.**

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The present invention relates to improvements brought to the subject of Patent No. 1,557,212 of February 22, 1968, for "Bifocal contact lens." More particularly, it relates to a contact lens with continuously changing focal length.

Bifocal contact lenses have already been produced, notably in accordance with the above-mentioned patent. Such lenses are, in general, made in the same way as the bifocal lenses used in conventional eyeglasses, in the sense that there is a more or less clear line of demarcation in these lenses. The user must look through one portion of the lens to obtain distance vision, and through another portion of the lens to obtain near vision.

In the case of conventional eyeglasses, the user can generally use bifocal lenses without too much difficulty. Usually, he looks directly in front of him through the upper part of the lenses for distance vision, and he lowers his sight to see through the lower portion of the lenses for near vision.

Bifocal contact lenses have already been produced to be used in practically the same way. A problem that is much more difficult to solve is posed, however, regarding the training of the user in their use for distance vision and for near vision. Given that these lenses are placed directly on the eye, there is obviously only a very limited margin of displacement of the eye for one portion of the lens to be used in preference to another portion of it. Moreover, any displacement of the lens relative to the eye will be accompanied by the necessity of a corresponding readjustment on the part of the user, which further complicates the use of lenses of this type.

Contact lenses with tiny perforations have also been proposed, such as those described in the article "Bifocal Contact Lenses," published by The Precision-Cosmet Digest of March, 1962, pages 1 to 6. However, experience showed that this type of lens had an unfavorable effect on the peripheral vision, on the vision in case the lens is off center, and on the quantity of light transmitted. In consequence, their use is very limited.

The main objective of the present invention is to make a contact lens with continuous variation of the focal length, which will eliminate many of the difficulties encountered in the use of the bifocal contact lenses known up to now.

Another objective of the invention is to make a contact lense with continuous variation in focal length and of the type described that can be made and adjusted without significant difficulty, thus permitting a relatively economical use of these lenses.

Another objective of the invention is also to make a contact lens with continuous variation in focal length in part using the principle of the lenses with tiny perforations, but having other important characteristics that avoid the difficulties previously encountered, and in which the variation in focal length is virtually continuous.

Yet another objective of the invention is to make a contact lens of the type described that can be easily produced as a cosmetic contact lens.

These objectives and still other objectives of the invention will appear from the description of variant executions given solely as non-limiting illustrations and represented in the attached drawings in which:

Figure 1 is a cross-sectional view of a contact lens in conformity with the present invention, and

Figures 2 to 10 represent different dispositions of the pupil zone in these lenses.

The contact lens can be made in the usual way; it will for example be of the kind described in US Patent No. 2,510,438. These lenses are of the so-called corneal type, comprising a pupil zone and an iris zone surrounding the latter. It is to be understood that the invention is also applicable, however, to contact lenses other than those of the corneal type.

The demarcation between the pupil and the iris of a human eye is not precisely defined, because the diameter of the pupil varies inversely with the intensity of the light it receives, and also because of the inherent characteristics of the eye of the user. Therefore, in the present description and in the attached claims, when the "iris zone" and the "pupil zone" of the lens are referred to, it is to be understood, as will easily be comprehended by one skilled in the art, that these expressions designate the usual zones of the lens that are superposed on the pupil and on the iris surrounding it.

The contact lens in conformity with the present invention has the general shape of a meniscus, the concave surface of which is applied over the cornea and floats on it. The curvature of the concave surface of the lens is, overall, in conformity with that of the cornea; but this conformity is not complete. This is partly due to the limitations imposed in practice by the manufacture of the lenses, and sometimes also to variations in shape deliberately introduced for specific reasons. Thus, for example, a certain deformation is introduced near the center of the lens and of the cornea, to assure the presence in this location of a film of lachrymal fluid. Other

variations in shape can be provided, particularly on the periphery of the lens, for example as described in the above-mentioned US patent.

According to the principles of the present invention, the pupil zone of the lens includes a central part that is transparent to light. This central part is surrounded by an opaque region, which on its inside borders the pupil of the eye and which can cover the whole of its iris. The opacity of this region is interrupted by parts transparent to light, located in the pupil zone, so that the light that hits the lens passes through its central zone, and also through the said transparent parts arranged in the opaque region. This opaque region is limited in its extent so that at its periphery the light can pass through the lens.

The transparent central part of the lens effectuates the optical correction necessary for good distance vision. Experience has shown that lenses constructed in this way automatically permit distance vision because their wearer normally looks at distant objects through their transparent central part, but it has been observed, not without surprise, that the lenses described also permit close vision, even if no specific optical correction is made on the outside of the transparent central part of the lens. It follows that the optical correction for distance vision can be extended over the whole surface of the lens, or that it is possible for no optical correction to be made in the zone that surrounds the central part of the lens. Experience has shown that whatever the solution adopted, the transparent parts arranged in the opaque zone, in cooperation with the transparent central part of the lens, permit near vision and assure an adequate field of peripheral vision and a satisfactory illumination of the retina, the other zones of the lens located beyond the periphery of its opaque zone cooperating with the transparent parts arranged in this opaque zone to prevent blindness of the eye in case the lens is off center.

The lenses in conformity with the present invention are differentiated from the standard bifocal lenses by the fact that, in the latter, two different optical corrections are effectuated to permit distance vision and near vision, respectively. As has already been indicated, the variation in focal length is continuous, because the user does not perceive any demarcation between the near vision and distance vision zones. No correction is provided in this lens other than that necessary for distance vision, its transparent central part and the other transparent parts provided in its opaque zone adequately and automatically assuring near vision. The lens in conformity with the invention thus does away with the disadvantages of bifocal lenses with tiny perforations. In this lens, the peripheral vision is in no way impaired, completely adequate illumination of the retina is obtained, and procedures for maintenance of position which require normal centering of the lens can be used because normal vision is assured even in the case where the lens is off center.

The lens 10 shown in Fig. 1 includes a pupil zone 12 and an iris zone 14 surrounding it. In conformity with the present invention, the pupil zone includes opaque regions separated by transparent parts that let the light pass.

Fig. 2 shows a particular method of execution of the lens. The lens includes a central portion 13, transparent to light and located in the pupil zone 12. This central part is surrounded by opaque regions 15 separated from each other by transparent parts 16, which form the same number of slits for the passage of light. The opaque regions 15 are delimited on the exterior by semicircular recesses 19 which act as auxiliary perforations in case of off-centering of the lens.

The lens in Fig. 2 can for example have a outside diameter of 9 mm, the circle that circumscribes its opaque regions 15 having a diameter of 4.5 mm. Its central part 13 can have a diameter of 1.5 mm and its transparent parts 16 can have a length of 1.5 mm and a width of 0.4 mm.

The dimensions of contact lenses vary from one user to another. However, experience has shown that, for an average user, the transparent central part located in the pupil region, if it is circular, should have a diameter of between 1 and 2 mm, which gives a light passage area of between 0.8 and 3.14 mm^2. In the case of a user whose vision requires a high positive correction, the diameter of this region can be as low as 0.5 mm. The opaque areas that surround the transparent central part should have a width of at least 0.5 mm in all radial directions, except in the parts adjacent to the transparent parts that separate them. In order to assure the passage of a sufficient quantity of light, and to permit distance vision in case the lens is off-center, these opaque areas should extend over a distance of at least 1.0 mm, and at most 3.0 mm, starting from the center of the pupil zone 12. Under these conditions, the diameter of the circle that circumscribes these opaque areas is essentially the same as that of the pupil of the average user under normal illumination (about 110 new lux). The transparent parts 16 should have a minimum dimension of between 0.2 and 0.7 mm in all directions.

The wearer of these lenses places one on each eye in the usual way. An optical correction for near vision can be provided without difficulty, at least in the central region 13. Although it may be surprising, the presence of the transparent central part 13 and of the radial transparent parts 16 that separate the opaque surfaces 15 from each other simultaneously assures near vision, a sufficient field of vision, and the passage of sufficient light. These results can be obtained without any optical correction in the part of the lens outside its transparent central part 13 but, for ease of cutting, an optical correction is generally provided over the entire surface of the lens.

The lenses in conformity with the present invention can include opaque parts of various colors for cosmetic reasons. The term "opaque" as used in the present description is also to be understood to define semiopaque parts absorbing at least 50% of the incident light, since the main purpose envisaged is to avoid the passage of a significant quantity of light except in the radial transparent parts 16.

The desired color of the pupil and iris zones can be effectuated by any standard procedure, either by incorporation of pigments into the glass of the lens, or by surface application of an opaque paint. The most natural cosmetic effect is obtained when the lens includes regions 15 that are black opaque (or colored so as to absorb at least 50% of the incident light), circumscribed by a circle of diameter equal to that of a pupil under normal lighting conditions. A blue, green, brown, or other colorant, preferably more transparent to the light, can be incorporated into the glass of the lens in the part outside the iris zone, but this zone is generally left completely transparent to assure adequate illumination of the retina.

With regard to the optical corrections that these lenses of continuously variable focal length are to assure, the vision characteristics of the user for whom they are intended should obviously be taken into consideration. Since these vision characteristics vary considerably from one individual to another, and a lens suitable for a particular user is not suitable for another, as a consequence, and according to the present invention, the execution of a variety of lenses is provided for in which the opaque areas have various configurations. However, experience has shown that, apart from the lens shown in Fig. 10, a satisfactory lens should not have any interruption between its central part and its transparent peripheral part. Thus, the advantages of the invention are not obtained when the transparent slits 16 start from the periphery of the opaque surfaces, but stop at a not insignificant distance from the periphery of the transparent central part 13.

The presence of the recessed semicircles 19 is desirable in that it increases the quantity of light transmitted to the retina, and in that each of them acts as an auxiliary pupil, in case of the off-centering of the lens, which increases the permissible tolerance in the position of the lens on the eye. The area of the remaining opaque surfaces is still sufficient to retain the advantages of the combination of the opaque regions and the transparent radial parts of the lens, but the presence of these recessed semi-circles is not necessary in all cases. Figure 3 shows for example another method of execution of the lens in which the opaque regions 17 have the form of a collar of segments in a ring, not limited on the outside by recessed semi-circles such as 19.

Figures 4 to 10 show various other methods of execution. The lens in Fig. 4 includes eight opaque segments 15 instead of six. Figures 5, 6 and 7 show different methods of execution of the lens in which the transparent radial interruptions of the opaque parts have different shapes. These transparent interruptions can have the shape of arcs of a circle 22 in Fig. 5, that of arms of a star 24 in Fig. 6, or rays 25 in Fig. 7. The lens in Fig. 8 includes opaque rectangular radial parts 28, and it is evident that these opaque parts could also very well have a form other than rectangular. In the lens in Fig. 9, the opaque parts 30 are delimited by semi-circular recesses 32 which are tangent to the transparent central part 13. The presence of these semi-circular recesses is desirable because of the fact that they take the place of auxiliary transparent zones which complete the transparent central part 13, in case the lens is off-center.

It is obvious that transparent radial parts of other shapes, and other attached transparent parts could also be provided, and one skilled in the art of such lenses can determine the most satisfactory configuration to be given to the various parts of the lens by a study of the vision characteristics of the subject. It is however provided according to the invention that the optimal configuration to be given to the lenses will be determined by the use of equipment that permits lenses of various configurations to be tried on a subject.

The opaque surfaces of the lens in Fig. 10 are constituted of concentric rings 34, 36 and 38 which are separated by transparent annular parts 40 and 42. Although in this lens the transparent parts 40 and 42 do not communicate with the transparent central part 13, experience has shown that this type of lens permits the aimed-for results to be obtained. The transparent annular parts constitute an optical system that concentrates the incident light rays on a focal point. Vision is not eliminated by the lens being off-center, and the amount of light transmitted to the retina is appropriate.

The various lenses described all permit the disadvantages of contact lenses with tiny perforations to be avoided. When only one of these perforations is provided on a lens, the amount of light transmitted and the peripheral visual field are reduced unacceptably. In addition, the wearer of these lenses is completely blind if the lens becomes off-center due to fluttering the eyelids or for any other reason. It has been attempted to remedy these disadvantages by the use of multiple perforations, but this solution caused diplopia (double vision) or polyopia (multiple vision).

The simplicity of the lenses described compared with the standard bifocal lenses is obvious. The processes used for the production of cosmetic lenses can be adapted without difficulty to the production of the lens in conformity with the invention in which the focal length varies continuously. These lenses do not require any special training of the wearer, since the latter does not have to find

the demarcation between two segments with different focal lengths to pass from distance vision to near vision, and vice versa. The wearer of these lenses can keep his head in the normal reading position at all times. The lenses described should be cut so as to effectuate the accommodation necessitated by the vision characteristics of the wearer. It is moreover important to note that these lenses have a natural appearance because they can be colored without difficulty. In this regard, different iris colors can be used for esthetic reasons.

Another major advantage of the lenses in conformity with the invention consists in their ease of fixation. It frequently happens that the placement of standard lenses, especially bifocal lenses, is extremely difficult because of the fact that a certain displacement of the lens on the eye is necessary to obtain correct vision. Experience has shown that in the case of the lenses described here, in which the focal length varies continuously, this fixation is not so critical because it is sufficient for the lens to be centered normally on the eye.

Of course, the invention is not limited to the methods of execution described, but encompasses all variants that conform to its spirit.

CLAIMS

1. Contact lens in the form of a meniscus in which the concave surface is provided for adhering to and floating on the cornea, and in which the curvature conforms to that of the cornea, the said lens including a central pupil zone and an iris zone surrounding this central zone, characterized by the fact that the said pupil zone includes a central region transparent to light, a practically opaque region surrounding this transparent central region, the opaque region extending radially starting from the said pupil zone, over a distance relative to the center of this zone of between 1.0 and 3.0 mm, a plurality of parts transparent to light subdividing the said opaque region, each being situated at least in part in the said pupil zone, the said transparent central region situated in the pupil zone effectuating the optical correction required for distance vision, the said central region coming into combination with the said transparent parts that subdivide the opaque region of the lens to effectuate a continuous variation of the focal length of the lens, and to assure a suitable peripheral field of vision as well as adequate illumination of the retina.

2. Lens as in claim 1, characterized by the fact that its opaque region is generally circular in shape and of a diameter essentially equal to that of the pupil of the wearer under normal lighting conditions.

3. Lens as in claim 1, characterized by the fact that its central transparent region has an area of between 0.8 and 3.14 mm^2.

4. Lens as in claim 1, characterized by the fact that its opaque region permits no more than 50% of the incident light to pass through.

5. Lens as in claim 1, characterized by the fact that its iris zone is colored in such a way as to have the natural color of the iris of an eye.

6. Lens as in claim 1, characterized by the fact that the said transparent parts that subdivide the opaque surface constitute a plurality of passages for the light in the form of oblong radial slits.

7. Lens as in claim 1, characterized by the fact that the said transparent parts that subdivide its opaque region constitute passages of light in the form of oblong slits directed radially towards the exterior and starting from the said pupil zone.

8. Lens as in claim 1, characterized by the fact that the said transparent parts are delimited by recessed or concave lines that are tangential to the said central transparent region.

9. Lens as in claim 1, characterized by the fact that its opaque region is formed of rings concentric with its transparent central region, separated by transparent rings that constitute the transparent parts.

Plate I-2

FIG. 1

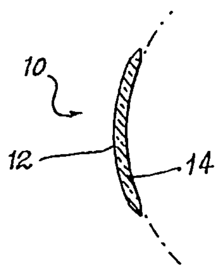

FIG. 2

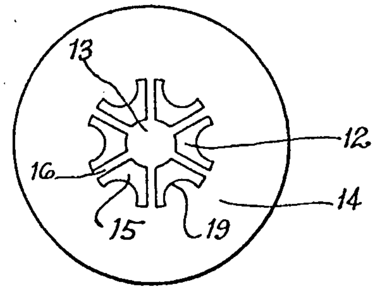

FIG. 3

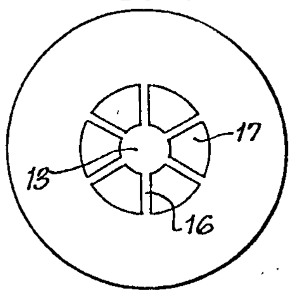

FIG. 4

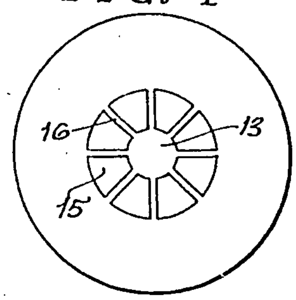

FIG. 5

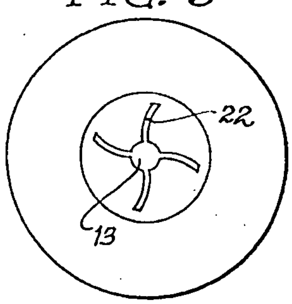

FIG. 6

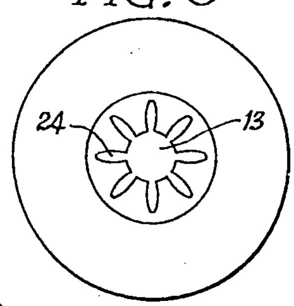

FIG. 7

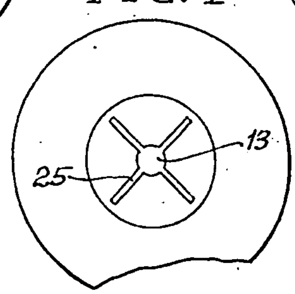

Plate II-2

FIG. 8

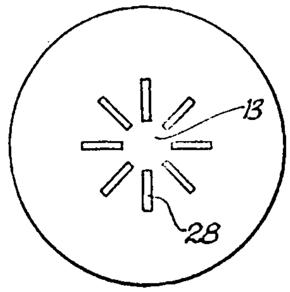

FIG. 9

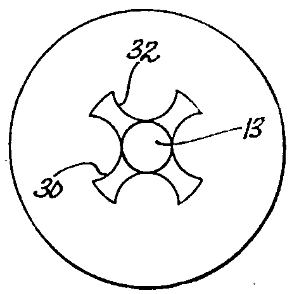

FIG. 10